

## Quarterly Report

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### A) Near-term Objective

To investigate the effect of surface emissivity variations on surface temperature estimations.

To develop a practical method of land surface emissivity/temperature measurements in the field.

To continue the inquiry of commercial spectroradiometers suitable for land surface emissivity and temperature measurements.

### B) Task Progress

1. The regional and seasonal dependences of the effect of surface emissivity variations on surface temperature estimations. Because the atmospheric temperature and humidity profiles vary with region and season, downward sky thermal infrared radiance varies accordingly. Therefore, the reflected sky radiance at the surface changes with surface emissivity through surface reflectivity. In case of land surface temperature equal to the air temperature at the surface, the NOAA7 AVHRR band 4 brightness temperature near nadir will change 0.45, 0.29 and 0.18K in subarctic winter, mid-latitude summer and tropical, respectively, as the emissivity of a Lambertian grey surface changes 0.01. They are 0.48, 0.21 and 0.10 K, respectively, for band 5. If we assume that the multi-channel SST (MCSST) algorithm with different offset terms approximately works for Lambertian land surfaces. In order to study the effect of emissivity spectral variation on surface temperature estimation, we compared results for different emissivities of AVHRR bands 4 and 5 to results for a grey surface with the averaged emissivity of these two bands. We describe the effect by the range of band emissivity difference between bands 4 and 5, where the modified MCSST changes less than 1 K. It is from -0.007 to 0.007 in subarctic winter, from -0.013 to 0.013 in mid-latitude summer, and from -0.022 to 0.022 in tropical. This means that the effect of emissivity variations is more significant under cold weather conditions due to less absorption of the atmosphere and less compensation by the reflected sky thermal infrared radiance at the surface. So the uncertainty in land cover emissivities becomes a major difficulty in land-surface temperature estimations from space under the cold weather condition.

2. I have got some AVHRR data, SST data, atmospheric temperature and humidity profiles from Ian Barton in September 92. Using some of these profiles, radiative transfer simulations have been made in order to quantitatively validate our accurate radiative transfer model ATRAD. It was found that sea-surface emissivity

model has a significant influence on the simulation results. Different treatments of the refractive angle in Fresnel formulae give different results of sea surface emissivity at large incident angles (as the incident angle is larger than 60 degree, emissivity could differ more than 0.01 at wavelengths longer than 11.5 micron). According to the basic theory of electromagnetic field, a complex refractive index should be used to calculate the refractive angle. As wind speed increases, sea surface reflection is no longer specular, therefore sea surface reflection pattern and emissivity changes with wind speed. So it is difficult to make a quantitative comparison without wind speed and sky radiance data. I have asked Ian Barton to provide these additional data. But these data are in the archives so that it may be difficult to find them.

3. A practical method of land surface emissivity and temperature measurements. Based on laboratory and field measurements of land surface emissivities made at NASA/Lewis Research Center in April 92, and radiative transfer simulations, an error analysis has been made for three basic assumptions in most emissivity measurements (i.e., surface temperature not change, emissivity not change, and Lambertian reflectance). It is found that the surface temperature usually changes with external radiation sources. Use of the solar beam as an external radiation source has advantages in its easy to control in the field and in estimating the surface temperature change. A four-step method (to measure radiances from a target surface and a reference surface under sunshine and shadow, respectively) gave some encouraging results. It will be refined in the near future when a thermal infrared spectroradiometer is available.

4. The effect of band-to-band misregistration on surface temperature estimations. In accordance to make comments for the MODIS data product and instrument descope options, I have made some simulations to evaluate the effect of the band-to-band misregistration on surface temperature estimations. We assume that the MCSST algorithm with different offset terms approximately works for Lambertian land surfaces. Suppose that a land with surface temperature 309.7 K is connected to a lake with surface temperature 299.7 K in a tropical region, so the temperature difference is 10 K (it is not an extreme example). Assume that both land surface and lake surface is a Lambertian surface with emissivity of 0.99. If one pixel of NOAA7 AVHRR band 4 and 5 is a pure pixel of land surface, and this pixel is mixed with lake surface in another band because of band-to-band misregistration, the difference between the model temperature and the averaged real surface temperature of this pixel is about 1.5 K and 3K, for misregistration of 0.1 and 0.2 pixel, respectively. Therefore, land surface temperature algorithm requires a good band-to-band registration.

5. In order to find out a commercial spectroradiometer most suitable for land surface emissivity and temperature measurements, I am making a continuous inquiry about optics design, performance,

and price. So far, I have got information on three kinds of TIR spectral radiometers, i.e., optics based on circular variable filter, grating and interference. Major concerns are operational temperature measurement range, instrument noise level and calibration accuracy. I have spent quite a lot of time on analysis and evaluation of different calibration methods.

#### C) Anticipated Activities During the Next Quarter

1. To continue on the items in A).
2. To prepare land-surface temperature algorithm for peer review.

#### D) Problems/Corrective Actions

Problem: Tmax 328 K for MODIS band 22 (3.959 micron) may be saturated. Simulation results for Sahara desert in daytime: using LOWTRAN7 for mid-latitude atmospheric profile at latitude 23 deg. N and longitude 0 deg. at 13:30 ST on day-of-year 244 under conditions of surface visibility 23 km (at 0.55 micron), surface temperature  $T_s = 335$  K and surface emissivity = 0.65 gives  $L_{max} = 2.05$  W/(m<sup>2</sup> um sr), Tmax = 330.4 K Action: to recommend a change of Tmax from 328 K to 332 K for MODIS band 22.

#### E) Publications

1. (invited paper) J. Dozier and Z. Wan, Development of practical multiband algorithms for estimating land-surface temperature from EOS/ MODIS-N data, COSPAR 92, Washington, DC, 28 August - 5 September, 1992. (submitted to journal of Advances in Space Research)
2. (contributed paper) Z. Wan, D. Ng and J. Dozier, Spectral emissivity measurements of land-surface materials and related radiative transfer simulations, COSPAR 92, Washington, DC, 28 August - 5 September, 1992. (submitted to journal of Advances in Space Research)
3. (abstract of presentation) Z. Wan, Requirements for ground-based IR measurements in development and validation of EOS/MODIS land-surface temperature algorithm, Capistrano Conference on Infrared Spectroscopy of Surfaces, San Juan Capistrano, California, August 3-6, 1992.